

CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-216

ROSE CANYON FAULT ZONE
San Diego County, California

By
Jerome A. Treiman
~~July 10, 1990~~
revised January 25, 1991

INTRODUCTION

The Rose Canyon fault zone extends south-southeast through the San Diego Metropolitan area and consists of several fault strands displaying normal, reverse, and right-lateral components of displacement. The fault zone extends offshore at La Jolla and continues north-northwest subparallel to the coastline as a zone of en echelon faults. To the south of the San Diego downtown area the fault zone appears to splay out into a group of generally south-trending right-normal oblique faults extending into San Diego Bay (Figure 1).

The purpose of this evaluation is to address new data indicating Holocene activity on a well-defined portion of the Rose Canyon fault zone between La Jolla and Clairemont as well as to assess new data relevant to the downtown area. These areas are included in the La Jolla and Point Loma 7.5 minute quadrangles. Previous Fault Evaluation Reports concerning the Rose Canyon fault zone were prepared by Saul (1979; FER-80) and by Kahle (1988; FER-196).

SUMMARY OF AVAILABLE DATA
Up to 1984

Data available through 1984 has been summarized in an unpublished report by Treiman (1984). Briefly, the Rose Canyon fault zone, onshore, was mapped as three dominant strands in the vicinity of Soledad Mountain (Rose Canyon, Mt. Soledad and Country Club faults) and two strands adjacent to Mission Bay and south of Mission Valley (Mission Bay and Rose Canyon or Old Town faults) (see Figure 2). These faults are largely based on Kennedy (1975). To the south, beyond Old Town, the fault zone may be expressed as a set of more southerly trending faults, including the Spanish Bight, Coronado and Silver Strand faults offshore and a group of unnamed south-southeasterly trending faults in San Diego Bay. Related faults probably cut through downtown San Diego. The San Diego fault, south from Broadway between Front and First Streets, and an inferred extension of the Coronado fault (Figure 5b, loc. 19 and 21) showed probable late Pleistocene but no documented Holocene displacement. Extensions farther south, into Mexico, have been postulated to step right offshore to the Descanso fault, or onshore

either through the coastal area to the Los Buenos fault or southeasterly through the Tijuana area to connect with the Vallecitos fault. Offshore to the north of San Diego the fault zone roughly parallels the coast until offshore from Carlsbad where it changes trend and becomes part of the South Coast Offshore Zone of Deformation (Figure 1).

Up through 1984 information on recency of faulting was limited (Treiman, 1984). The most recent onshore displacement was bracketed between $28,700 \pm 1500$ years (Figure 5a, loc. 14; Liem, 1977) and 1140 ± 80 years (Figure 5a, loc. 1; Artim and Streiff, 1981; Streiff and others, 1982). A possible constraint on the age of faulting along the Mount Soledad fault was presented by Berggreen and Streiff (1979) who described a landslide which lies across a trace of the fault (Figure 5a, loc. 9; also see Woodward-Clyde Consultants, 1979). Their studies showed that a fault strand observed in a trench was overlain by an unfaulted landslide and that in another locality the toe of the landslide overrode soils dated at about 9000 ybp. Their conclusion was that the landslide must have moved around 9000 years ago and that the fault has not moved since. This issue is explored further under Discussion and Conclusions. Possible Holocene displacement on some of the north-south trending offshore faults south of San Diego is suggested from seismic reflection profiles (Kennedy and Welday, 1980; Moore and Kennedy, 1975).

Post 1984

Significant findings have been made in several areas since the report by Treiman (1984). In the La Jolla area Kahle (1988) noted geomorphic features indicative of recent faulting (Figure 5a, loc. 25). He described a right-laterally offset alluvial fan and two right-laterally offset drainages. He also noted some possibly left-deflected drainages and a suggestion of vertical offset as well, up on the north. A brief note by Thomas (1985) described a linear zone of foundation and ground cracks which fall on the northwest projection of the photo features described by Kahle (1988). Thomas detected very minor right-lateral offset along the foundation cracks and noted that the deformation had been "slow and continuous" over many years. (It should be noted that fault creep has never been reported on this fault zone). Farther northwest, offshore in the La Jolla submarine canyon (Figure 5a, loc. 26), Holocene displacement was interpreted by Judy (1987) who used SCUBA to observe 8000 to 12,000 year old radiocarbon-dated submerged lagoonal sediments which are deformed, truncated, and presumed to be faulted against an undated submerged terrace deposit.

Southeast from La Jolla, along the east flank of Soledad Mountain, and along Rose Creek, numerous geomorphic features have been identified associated with the Mount Soledad fault and the Rose Canyon fault (West, 1987; Kahle, 1988; Lindvall, Richter & Associates 1989). West (1987) measured right-lateral offsets or deflections ranging from 7 to as much as 40 meters. A strand of the Mount Soledad fault was exposed during grading for a buttress stabilization in the Ridgeway tract (Leighton and Associates,

1988a) but Holocene deposits were not observed in the fault zone (Figure 5a, south of loc.9). Possible isolated geomorphic indications of faulting, other than along these two main faults, were described by West (1987; channel wall offset along the Country Club fault) and by Kahle (1988; hillside bench near the Rose Canyon fault, Figure 5a, loc. 24).

The most youthful looking features, at the mouth of Rose Canyon (Figure 5a, loc. 23), include scarps, pressure ridges, a closed depression, a linear bench, an offset channel wall (110 feet right-lateral) and several deflected drainages (West, 1987; Kahle, 1988; Rockwell and Lindvall, 1990). These features are not on a previously mapped trace, but are close to a fault interpreted by Kies (1979; Figure 5a, loc. 7), which is also shown by Leighton and Associates (1983). In 1989 a trench was excavated across one of these features (Figure 5a, loc. 23a), a scarp (now buried under artificial fill) identified in old aerial photographs (Lindvall Richter Associates, 1990; Lindvall and others, 1990; Rockwell and Lindvall, 1990). This trench exposed faulted Holocene deposits including truncated A and B soil horizons. The trench exposure (Figure 3) included evidence of multiple Holocene displacements with 1.4 m apparent vertical separation (northeast side down) of an 8300 ± 580 year old horizon and about 40 cm vertical separation of the base of the B horizon. An indeterminate but dominant amount of strike-slip movement was inferred from mismatched stratigraphy. The principal fault strand strikes N45°-50°W and dips steeply to the southwest. South of the trench Rockwell and Lindvall (1990) reported several drainages deflected right laterally as much as 70-90 m (Figure 5a, loc. 27).

No new data has been developed for the Rose Canyon fault zone between Clairemont Drive and downtown San Diego since 1984. Several investigations in the downtown area, however, have uncovered additional strands of the probably complex zone of faulting at the southern end of the fault zone (Figure 2, loc. 22; Figure 5b). A study for the Police Administration and Technical Center (PATC, loc.22a) investigated three faults within the block bounded by 14th St., E St., 15th St. and Broadway (Testing Engineers and others, 1985; Patterson and others, 1986). The central fault at this site trends north-northwesterly and clearly displaced late Pleistocene and possibly Holocene units. The report described progressively decreasing vertical separation (west-side down) of stratigraphic units estimated to be 15-20 thousand years old, 10-15 thousand years old, 5-10 thousand years old and possible displacement of a soil estimated to be 3 to 5 thousand years old. There was no indication of Holocene displacement on the eastern or western faults, which trend north-northeasterly. A second-party review of this report, by Leighton and Associates (1985), disagreed on the youth of the units displaced and on whether the youngest unit was displaced at all; they felt that the youngest clearly displaced unit was at least 20,000 years old, and that the overlying soil was probably not displaced. Tom Rockwell, (personal communication, 1990) however believed, based on initial exposures, that the uppermost stratigraphic unit (soil) was Holocene and was faulted. Earl Hart (field notes, 6/5/85) observed weak sub-

horizontal striations in and near the central fault zone which suggest a dominant strike-slip component of slip.

To the south of PATC another fault was uncovered during construction of Jerome's Warehouse (Sangines and Reed, 1986). This fault, near the northeast corner of 14th and F streets (Figure 5b, loc.22b), trends N17°W and dips steeply northeast. Vertical separation increases with depth to as much as 18 feet separation of an upper Pleistocene gravel (east side down). Changes in stratigraphic thickness across the fault suggest a lateral component as well. The soil preserved at the site was estimated to be 3000 to 5000 years old and, although uncut, appears to drape over the fault, with a 1 to 2 1/2 foot vertical separation of the E-horizon.

To the north of PATC, on the north side of Broadway, an investigation by Leighton and Associates (1988b) exposed a zone of faulting which lies on trend with the Central fault at PATC. The main fault exposed has a strike of N12°W and dips 82°W with an apparent vertical separation of at least 6 feet, west side down, based on displaced terrace deposits, and 2.5 feet based on topsoil. Leighton and Associates (1988b) consider this fault to be associated with the central fault, on trend to the south. Another roughly parallel fault, but dipping 83°E, was found 20 feet to the west. This fault has a gouge zone 4" to 6" thick but does not fully penetrate a late Quaternary terrace deposit.

One street to the north Owen Consultants exposed the probable continuation of this zone of faulting. A trench and borings excavated at 14th and C streets revealed a roughly thirty foot apparent offset in the elevation of the top of the San Diego Formation in the subsurface as well as faulting and warping of a buried soil and some of the overlying aeolian sand (Owen Consultants, 1989 and 1990b). A lesser fault, 85 feet to the east, displaced San Diego Formation less than six feet vertically.

Two blocks to the west, between 12th and 13th Streets, another fault has been defined trending N10°W between C Street and E Street (Figure 5b, loc.22c). This fault was exposed in three trenches and consistently juxtaposed San Diego Formation (on the west) against late Pleistocene sand, silt and gravel (on the east). In one exposure a 290 ± 80 year old (radiocarbon age) soil or colluvial wedge above the fault contained several fractures or possible shears (Owen Consultants 1989, 1990a,b). This fault, along with the fault zone at PATC, define a structural graben.

No new data south of the downtown area since Kahle's (1988) report has come to our attention.

SEISMICITY

San Diego has generally been considered to be an area of low seismicity, however a look at the records indicates many events which might be associated with the Rose Canyon fault zone. Topozada and others (1981) show two pre-1900 earthquakes (M>3)

possibly along the fault zone, one offshore north of La Jolla (pre-1850) and one in the San Diego Bay (1862). No earthquakes ($M > 4$) are indicated for the fault zone from 1900-1931 (Toppozada and others, 1978). Figure 4 (from Heaton and Jones, 1989) shows the epicenters of earthquakes greater than $M 2.3$ for the period 1975 - April 1989. The pattern shown is typical of the instrumental seismicity recorded since 1932 (see for example Treiman, 1984, figure 5a; Simons, 1979).

Notable in the instrumental record are the numerous epicenters in the San Diego Bay area including a cluster of events in 1964 (Simons, 1979) and 1985 (Reichle and other, 1985). The earthquake swarm in 1985 included three shocks around $M 4$ and fault plane solutions showed primarily strike-slip motion parallel to mapped faults. No surface rupture has been observed with any of the historic seismicity.

AERIAL PHOTO INTERPRETATION

Due to the extent of development in the San Diego area, vintage air photos have been the primary means of assessing fault expression. Three sets of aerial photographs were used for this evaluation: from 1928/29, 1941, and 1953 (see Table 1). Independent interpretation verified many features noted by Kahle (1988), Lindvall, Richter and Associates (1989), Rockwell (personal communication, 1989) and West (1987), and many additional features have been noted (Figure 5a,b). These features were plotted using a Bausch & Lomb stereo-zoom transfer/scope. Some features noted by others could not be verified. I did not feel that I could verify the precise displacement measurements of West (1987) due to the scale and resolution of the photos used.

In the La Jolla area (Figure 5a, loc.25) the right-lateral offsets of Kahle (1988) were verified but his observation of left-lateral deflection and vertical offset could not be repeated. Numerous indications of fault morphology were noted across the east flank of Soledad Mountain including linear drainages, notches, sidehill benches, tonal lineaments and several right-deflected drainages. Several large and small landslides locally mask the fault's topographic expression. Many of the linear drainages, saddles, and sidehill benches were previously identified by West (1987), but I did not agree with most of his lateral deflections or offsets. I found several other features though in this area which are supportive of a continuous, active, right-lateral fault. Most of the indicators of recent faulting on Soledad Mountain correspond with the Mount Soledad fault.

Within Rose Canyon there are minor features associated with the Mount Soledad and Rose Canyon faults. These include possible scarps and tonal lineaments along the projection of the Mount Soledad fault and deflected drainages, tonal lineaments and other topographic features along a strand of the Rose Canyon fault where it crosses Rose Canyon. The sidehill bench described by Kahle (1988, loc. 24) is weak and different slope texture above and below suggest a lithologic contrast. A pronounced linear drainage to the

northwest is probably controlled by a lithologic contact. What appears to be ponded water (near loc. 5a) west of the railroad tracks in the 1928/1929 photos may be a defect in the photograph as it does not appear on adjacent frames. A short tonal feature (near loc. 5b) appears to be a buried channel margin visible in the earliest photos. The deflected drainage (?) to the southeast may be an artifact of the railroad trestle. Less ambiguous features near Jutland Drive (loc. 6) suggest oblique extensional displacement. Right deflections of two tributary drainages to the south (adjacent to Avati Dr.), interpreted by West (1987), appear to be only tenuously fault related. Channel-wall offsets along the Country Club fault, identified by West (1987), could not be located. The freshest and most prominent features are at the mouth of Rose Canyon (near Pacific Beach; Figure 5a, loc.23 and 27) where an abandoned channel margin, and several tributary drainages are displaced right-laterally up to 230 feet (70 m). Two closed depressions, pressure ridges, scarps, tonal lineaments and slope breaks add to the indicators of recent displacement.

Between the offset drainages and Mission Valley are a few discontinuous tonal lineaments and linear troughs which are not necessarily indicative of recent fault movement. In the downtown area (Figure 5b), although the area is fully developed in the earliest photos available, a broad gentle swale is visible which is coincident with the graben identified by Owen Consultants (1989).

FIELD OBSERVATIONS

As indicated by Kahle (1988), current exposures are very limited. In June of 1984 I saw the features in La Jolla described by Thomas (1985; between loc.1 and 25, Figure 5a). A ground crack oriented roughly N25°W connected two cracked house footings. Displacement in the footings was less than 1 mm right-lateral. Along trend to the southeast the rear property wall was cracked. A very slight left-lateral shift in a cracked block wall across the street to the northwest was also noted, as well as tilting of a swimming pool. By themselves these features are not considered strong enough to attribute them with any certainty to faulting. A search was not made for similar features off-trend, and these observations may be just settlement phenomena. Lateral offsets observed are not consistent, persistent or necessarily significant.

The right-deflected drainage southwest of the Scripps School (Figure 5a, loc.25) is still observable, as are the obvious saddle and linear drainages near the Easter Cross on Soledad Mountain (loc.8). The Windemere and Ridgeway developments have obscured many features not otherwise overgrown with vegetation but the sidehill bench noted southeast of the Easter Cross is also still present. A fault trending N20°W and dipping 65°E was located as one of what are probably several shears in the linear drainage south of the "Trailer Park" notation on the base map, on the west side of Rose Canyon. Displacement of Holocene material was not observed here. I visited the trench at the San Diego Gas and Electric facility near the mouth of Rose Canyon (loc.23a) and agreed with the interpretation of field data as summarized in

Lindvall Richter Associates (1990) and Lindvall and others (1990). Although shears were not visible the truncation of stratigraphic units was relatively clear.

I also had the opportunity to observe two of the recent trenches in the downtown area (Figure 5b) and concur in general with the data presented by Owen Consultants (1989 and 1990a,b). The fault exposed at 14th and C St. trends N10°-20°W, dips steeply west, and clearly displaced a buried B soil horizon within one foot of the original ground surface.

DISCUSSION AND CONCLUSIONS

The principal active strand of the Rose Canyon fault zone corresponds largely with the Mount Soledad fault and a previously unmapped extension of this fault through Rose Canyon and adjacent to the northeastern part of Mission Bay. From Clairemont, adjacent to Mission Bay, to downtown San Diego scattered weak features suggest that fault displacement may be distributed across several minor faults but is not significant enough on any fault to be well defined as an active structure. The most recent faulting so far identified in the downtown area is concentrated south of Balboa Park and defines a northerly trending structural graben. Numerous geomorphic features elsewhere along the fault indicate that right-lateral strike-slip has predominated along the fault zone. Incomplete knowledge of local landform development prevents an estimate of recent slip rate.

The active fault segment in La Jolla (which follows, in part, the Rose Canyon fault of Kennedy, 1975, and also part of a shorter unnamed fault also shown by Kennedy) is well defined between Torrey Pines Road and a landslide above Hidden Valley Road based on features shown on Figure 5a (loc.25). Continuity to the shoreline is based on the admittedly tenuous observations of Thomas (1985), the trench location of Artim and Streiff (1981; loc.1), and the offshore fault exposure of Judy (1981; loc.26). Holocene displacement in the La Jolla area is strongly supported by the offset drainages and other features south of Torrey Pines Road and the Holocene displacement interpreted by Judy (1987) less than 2000 feet offshore.

Continuity immediately to the southeast from La Jolla is lacking, obscured for about 2000 feet in part by landsliding, but then is well defined by geomorphic features along the Mount Soledad fault from west of the Easter Cross to Rose Canyon, as mapped by Kennedy (1975). Many of the features across the eastern flank of Soledad Mountain, such as linear drainages, saddles and notches, could merely be fault line geomorphic features and do not necessarily support recency. Many of the subtler small-scale geomorphic offsets, however, are better indicators of fault sense, magnitude and recency.

Trench and borehole data from a landslide across the Mount Soledad fault, west of Rose Canyon (Figure 5a, loc. 9), have been interpreted to preclude fault movement within the past 8500 years

(Berggreen and Streiff, 1979), however a closer look at the data shows this constraint is more apparent than real. Although early Holocene material was incorporated in or overlain by the landslide (Woodward-Clyde Consultants, 1979: Figures A-23 and A-32) this does not necessarily prove that that was the minimum age of landslide movement and certainly does not constrain subsequent reactivation. Also, their figures A-23 and A-25 show that the slide plane which truncates the fault is relatively shallow (5 to 10 feet deep) whereas the large landslide which is supposed to date back to early Holocene is probably greater than 20 feet thick (as suggested by Woodward-Clyde, 1979 figures 6-C and A-13). The slide which truncates the fault is probably a subsidiary slide within the larger one and may be much younger than 8500 years old. Lastly, the overridden fault is probably a lesser splay of the Mount Soledad fault and does not correspond to any previously mapped fault nor to the most recently active trace as interpreted in this review. What appears to be the most recently active trace corresponds to a splay approximately 100 to 200 feet to the southwest as shown in part by Kennedy (1975). This splay projects through a zone of intense faulting with mismatched stratigraphy exposed in a buttress backcut by Leighton and Associates (1988a, Plate 3), and is defined by a possibly offset ridge, two offset drainages and other geomorphic features (Figure 5a).

Within Rose Canyon the projection of the Mount Soledad fault is largely obscured by modern stream processes, roads and a railroad line, even in the earliest aerial photos available. The northern part of this segment has probably controlled the relatively straight reach of Rose Canyon and may be responsible for some possible scarps and tonal features detectable in the 1928/1929 photos. In spite of development, the active fault is well defined from south of where it crosses Rose Creek almost to Clairemont Drive. Two main strands and some additional splays are defined in the vicinity of Balboa Avenue by scarps, benches, deflected drainages, closed depressions and pressure ridges (loc.23). South of Balboa Avenue the main strand is largely obscured by the railroad tracks but is still well-defined by numerous right-deflected drainages (loc.27). The drainages are incised through deposits dated at about 300,000 ybp (Kern and others, 1971; Karrow and Bada, 1980) and appear to incise younger, undated deposits as well. The age of these drainages is not well enough constrained, however, to derive a slip rate. Holocene displacement has been clearly demonstrated in a trench exposure across one of the strands north of Balboa Avenue (Lindvall Richter Associates, 1990; Lindvall and others, 1990; Rockwell and Lindvall, 1990; loc.23a).

On the east side of Rose Canyon, where the Rose Canyon fault (of Kennedy, 1975) crosses the canyon, there are several features identified in air photos. The most continuous and suggestive feature is an arcuate alignment of scarps, tonal lineaments and a narrowed, deflected drainage along what may be a splay of the Mount Soledad fault anastomosing with the Rose Canyon fault. The Rose Canyon fault does not otherwise appear to be active. A break in slope and a linear drainage align with a questionably deflected drainage and doubtful ponded alluvium to the northwest, but

trenches described by Farrand and others (1981) and Farrand (personal communication, 1983) crossed this alignment and exposed an unfaulted 7800 ± 500 year old paleosol (Figure 5a, loc. 5a) and 9970 ± 610 year old unfaulted alluvium (loc. 5b). Faulting along the mapped trace of the Rose Canyon fault at Jutland Drive (Figure 5a, loc. 6) does not correspond with any indicators of Holocene activity.

South from De Anza Cove the Mount Soledad fault may continue, perhaps as the Mission Bay fault (but in a slightly different location from that inferred by Kennedy, 1975). It is not expressed at the surface however, except as possibly a few discontinuous, subtle features between Bay Park and Mission Valley. Limited fault exposures in the same general area (summarized in Treiman, 1984) indicated late Pleistocene to possible Holocene faulting. Holocene displacement, if present in this area, may be distributed across several fault strands and may not be readily detectable.

The only evidence of Holocene activity south of Mission Valley is in the downtown area, south of Balboa Park (Figure 5b), where a locally defined structural graben corresponds to a broad subtle topographic swale. Data from numerous man-made exposures suggest that this structure has been active during the Holocene. Although the swale extends further to the south, at least as far as Commercial Street, it is very poorly defined and there is as yet no data indicating surface faulting south of F St. This trend aligns roughly with faults mapped in San Diego Bay and should be monitored for additional data.

RECOMMENDATIONS

I recommend zoning the fault traces as highlighted in yellow on Figures 5a and 5b. Holocene activity is documented in a trench exposure north of Balboa Avenue and by faulted sediments offshore from La Jolla. Geomorphic features in La Jolla, on Soledad Mountain, and south of Balboa Avenue are strongly suggestive of latest Quaternary faulting and in many cases are as well developed as those features at the trenched locality north of Balboa Avenue where Holocene soils have been displaced. In the downtown area Holocene or probable Holocene soils appear to be affected by faulting at several localities (PATC, Jerome's Warehouse, 14th and C St., 12th and C St.).

Continuity is demonstrated along several fault segments by numerous geomorphic features coincident with previously mapped fault traces. Continuity is inferred through La Jolla based on the trench at Spindrift (loc.1) and the active trace offshore. Continuity is inferred through Rose Canyon based on the unusual straightness of the canyon between two well-defined fault segments. Continuity is inferred roughly 4000 feet south of Balboa Avenue based on numerous aligned stream deflections. In the downtown area continuity is inferred based on the alignment of features between several man-made exposures and the general coincidence with topographic expression.

The Rose Canyon fault (except for one portion in La Jolla and one splay in Rose Canyon which may be more a part of the Mount Soledad fault), the Country Club fault, the Mission Bay fault south of De Anza Cove and the Old Town fault have not been shown to be sufficiently active or well-defined to warrant zoning at this time.

The recommended zoning on the La Jolla quadrangle is based on fault locations from Kennedy (1975), Artim and Streiff (1981), Lindvall, Richter and Associates (1989), and this Fault Evaluation Report. Recency was documented by Lindvall Richter Associates (1990).

The recommended zoning on the Point Loma quadrangle is based on fault locations from Owen Consultants (1989, 1990a and 1990b), Testing Engineers and others (1985), Sangines and Reed (1986), and this report. Recency of faulting was documented or strongly supported by these same sources.

*Report reviewed
& recommendations approved.
Earl W. Hart
CEG-935
1/25/91*

Jerome Treiman

Jerome Treiman
Associate Geologist
EG 1035

AERIAL PHOTOGRAPHS REVIEWED

San Diego County scale 1:13,000 ± 2000 b/w 8x10
Nov. 1928 to Mar. 1929

Fairchild Aerial Surveys scale 1:18,000 b/w 9x9
Flight C-6850 : frames 90-95 1/3/41
portions of frames 90, 91, 92 and 93 enlarged to 1:4800

USDA scale 1:20,000 b/w 9x9
Flight AXN 3M : frames 193-198 3/31/53
AXN 4M : frames 86-92 3/31/53
AXN 7M : frames 187-189 5/2/53
AXN 8M : frames 1-3 4/11/53

REFERENCES CITED

- Artim, E.R., and Streiff, D., 1981, Trenching the Rose Canyon fault zone: Woodward-Clyde Consultants, Final Technical Report, sponsored by U.S. Geological Survey, Contract No. 14-08-0001-19824, 28 p., App.
- Berggreen, R.G., and Streiff, D. 1979, Recency of faulting on the Mount Soledad branch of the Rose Canyon fault zone in northwestern metropolitan San Diego, California [abst.]: Geological Society of America Abstracts With Programs, v. 11, no. 7, p. 387.
- Farrand, G.T., Bemis, C.G., and Jansen, L.T., 1981, Radiocarbon dates of alluvium, Rose Canyon fault zone, San Diego, California [abst.]: Geological Society of America Abstracts With Programs, v. 13, no. 2, p. 55.
- Heaton, T.H., and Jones, L.M., 1989, Seismological Research Issues in the San Diego Region, in Roquemore, G., and Tanges, S., eds., Proceedings, workshop on "The seismic risk in the San Diego region: special focus on the Rose Canyon fault system", June 29-30, 1989: The Southern California Earthquake Preparedness Project, p.42-49.
- Judy, T.C., 1987, Reconnaissance geology of the Holocene lagoonal deposits in the La Jolla submarine canyon and their relationship to the Rose Canyon fault: [unpublished] in San Diego State University, Department of Geological Sciences, Undergraduate Research Reports, v. 49, 15 p.
- Kahle, J.E., 1988, A geomorphic analysis of the Rose Canyon, La Nacion and related faults in the San Diego area, California: California Division of Mines and Geology, Fault Evaluation Report FER-196, unpublished, 14 p., 1 pl. (1:100,000).
- Karrow, P.F., and Bada, J.L., 1980, Amino acid racemization dating of Quaternary raised marine terraces in San Diego County, California: *Geology*, v. 8, p 200-204.
- Kennedy, M.P., 1975, Geology of the western San Diego metropolitan area, California, Del Mar, La Jolla, and Point Loma quadrangles, in *Geology of the San Diego metropolitan area, California: California Division of Mines and Geology Bulletin* 200, p. 9-39.
- Kennedy, M.P., and Welday, E.E., 1980, Character and recency of faulting offshore, metropolitan San Diego, California: California Division of Mines and Geology Map Sheet 40, 1:50,000.
- Kern, J.P., Stump, T.E., and Dowlen, R.J., 1971, An upper Pleistocene marine fauna from Mission Bay, San Diego, California: *San Diego Soc. Nat. Hist., Trans.*, v. 16, p. 329-338.

- Kies, R., 1979, The Rose Canyon fault zone from Point La Jolla to Balboa Avenue, San Diego: [unpublished] in San Diego State University, Department of Geological Sciences, Undergraduate Research Reports, v. 35, pt. 3, 57 p., map 1"= 400'.
- Leighton and Associates, 1983, Seismic safety study for the City of San Diego: unpublished consultant's report prepared for City of San Diego, Leighton and Associates, July 8, 1983, Project No. 4810555-02.
- Leighton and Associates, 1985, Geotechnical Report Review of the "Geologic and Fault Investigation, San Diego Police Administration and Technical Center," City of San Diego, California: unpublished consultant's report to City of San Diego, August 21, 1985, Project No. 4810555-05.
- Leighton and Associates, 1988a, As-Graded Geotechnical Report of Remedial Grading, Lots 148 through 168, Ridgeway Row, Ridgeway I, La Jolla, California: unpublished consultant's report to AVCO Community Developers, Inc., Feb. 26, 1988, Project No. 4830339-05.
- Leighton and Associates, 1988b, Geotechnical Investigation, 1420-1434 Broadway, San Diego, California: unpublished consultant's report to Metropolis Investment and Development, Inc., July 12, 1988, Project No. 4880856-01.
- Liem, T.J., 1977, Late Pleistocene maximum age of faulting, southeast Mission Bay area, San Diego, California, in Farrand, G.T., ed., Geology of southwestern San Diego County, California and northwestern Baja California: San Diego Association of Geologists, p. 61-64.
- Lindvall, Richter and Associates, 1989, Seismic Study of Surface Rupture Hazard for SDG&E Pipelines 28 and 31, San Diego California: unpublished consultant's report to San Diego Gas & Electric Co., March, 1989, Project No. 131-002.
- Lindvall Richter Associates, 1990, Investigation of the Rose Canyon fault zone, SDG&E Beach Cities Operating Center, San Diego, California: unpublished consultant's report for San Diego Gas & Electric Company, June 1990, LRA No.131-003, 13p.
- Lindvall, S.C., Rockwell, T.K., and Lindvall, C.E., 1990, The seismic hazard of San Diego revised: new evidence for magnitude 6+ Holocene earthquakes on the Rose Canyon fault zone: Earthquake Engineering Research Institute, Proceedings of the Fourth U.S. National Conference on Earthquake Engineering, Palm Springs, California, May 20-24, 1990, Volume 1, pp.679-688.
- Moore, G.W., and Kennedy, M.P., 1975, Quaternary faults at San Diego Bay, California: U.S. Geological Survey, Journal of Research, v. 3, no. 5, p. 589-595.

- Owen Consultants, 1989, Geotechnical and Environmental Investigation, Proposed Civic Center Site, San Diego, California: unpublished consultant's report to City of San Diego, August 25, 1989, Project No. 115.116.1.
- Owen Consultants, 1990a, Addendum Number 1, Geotechnical and Environmental Investigation, Proposed Civic Center Site, San Diego, California: unpublished consultant's report to City of San Diego, February 21, 1990, Project No. 115.116.2.
- Owen Consultants, 1990b, Addendum Number 2, Geotechnical and Environmental Investigation, Proposed Civic Center Site, San Diego, California: unpublished consultant's report to City of San Diego, April 27, 1990, Project No. 115.116.3.
- Patterson, R.H., Schug, D.L., and Ehleringer, B.E., 1986, Evidence for recent faulting in downtown San Diego, California [abst.]: Geological Society of America, Abstracts With Programs, v. 18 no. 2, p. 169.
- Reichle, M., Bodin, P., and Brune, J., 1985, The June 1985 San Diego Bay earthquake swarm [abst.]: EOS, v. 66, no. 46, p. 952.
- Rockwell, T.K., and Lindvall, S., 1990, Holocene activity of the Rose Canyon fault in San Diego, California, based on trench exposures and tectonic geomorphology [abst.]: Geological Society of America, Abstracts With Programs, v. 22, no. 3, p. 78.
- Sangines, E.M., and Reed, L.D., 1986, Recent fault discoveries in downtown San Diego California [abst.]: AEG Abstracts and Program, 29th Annual Meeting October 5-10, 1986, San Francisco, p. 62.
- Saul, R.B., 1979, Preliminary fault evaluation report number 80; Rose Canyon fault: [unpublished report] California Division of Mines and Geology, January 5, 1979, 9 p., figs.
- Simons, R.S., 1979, Instrumental seismicity of the San Diego area, 1934-1978, in Abbott, P.L., and Elliot, W.J., eds., Earthquakes and Other Perils, San Diego Region: San Diego Association of Geologists, for Geological Society of America field trip, Nov. 1979, p. 101-105.
- Streiff, D., Schmoll, M., and Artim, E.R., 1982, The Rose Canyon fault at Spindrift Drive, La Jolla, California, in Abbott, P.L., ed., Geologic Studies in San Diego: San Diego Association of Geologists, Field Trips, April 1982, p. 28-34.
- Testing Engineers-San Diego, Dames and Moore, and Woodward-Clyde Consultants, 1985, Geologic and Fault Investigation, San Diego Police Administration and Technical Center: unpublished consultant's report to Starboard Development Company, May 17, 1985.

- Thomas, V., 1985, Letter to the editor: California Geology v. 38, no. 5, p. 114.
- Toppozada, T.R., Parke, D.L., and Higgins, C.T., 1978, Seismicity of California, 1900-1931: California Division of Mines and Geology Special Report 135, 39 p.
- Toppozada, T.R., Real, C.R., and Parke, D.L., 1981, Preparation of isoseismal maps and summaries of reported effects for pre-1900 California earthquakes: California Division of Mines and Geology Open-File Report 81-11 SAC, 182 P.
- Treiman, J.A., 1984, The Rose Canyon Fault Zone, A Review and Analysis: unpublished report for Federal Emergency Management Agency, coop. agreement EMF-83-K-0148; California Department of Conservation, Division of Mines and Geology, August 1984, 106 p.
- West, R.B., 1987, Tectonic geomorphology of the Mount Soledad segment of the Rose Canyon fault zone: [unpublished] in San Diego State University, Department of Geological Sciences, Undergraduate Research Reports, v. 49, 30 p.
- Woodward-Clyde Consultants, 1979, Geotechnical Investigation for the Proposed Ridgeway La Jolla Units 1,2, and 3, La Jolla, California: unpublished consultant's report to AVCO Community Developers, Inc. May 9, 1979 (rev. 12/31/79), Project No. 57378A-AS01.